Consumption, savings and demography

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Publication date:
1986

faculteit der economische wetenschappen

RESEARCH MEMORANDUM

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Consumption, Savings and Demography

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October 1986

*) Tilburg University. Financial support by the Netherlands Organization for the Advancement of Pure Research (ZWO) and by the NMB bank is gratefully acknowledged. We thank Raymond Gradus and Arie de Graaf for their research assistance and Yannis Ioannides, Bertrand Melenberg, Robert Moffitt, John Muellbauer and Theo Nijman for their valuable comments.

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Abstract

This paper estimates and tests an expected (multiperiod) utility maximization model of the joint determination of savings and of expenditures on different goods using panel data. The emphasis is on the estimation of within period preferences that are consistent with intertemporal two stage budgeting under uncertainty. The parameters of the intratemporal utility function depend on demographic factors in a flexible way.

We provide an alternative estimation method to the "λ- constant" approach of Browning, Deaton and Irish (1985) and to the "pseudo demand function" approach of Blundell and Walker (1986). Our approach allows for testing certain implications of the rational expectations-life cycle hypothesis along the lines of Hall (1978). The empirical results indicate rejection of the hypothesis and suggest the existence of liquidity constraints. However, for some forms of liquidity constraints the functional form of the within period demand functions is not affected. Therefore we have estimated a within period demand system, based on the Almost Ideal Demand System (A.I.D.S.) cost function.

1. Introduction

Since the path-breaking work of Modigliani and Brumberg (1955), many economists have paid attention to the Life Cycle Hypothesis. Recently, Heckman (1978), Heckman and Macurdy (1980), Macurdy (1981) and Browning, Deaton and Irish (1985) have analysed (and usually estimated) life cycle models of labor supply and consumption in which preferences are intertemporally additively separable and the marginal utility of wealth is treated as an unobservable individual effect. When panel data are available and the individual effects enter additively into within period demand functions, estimation of these functions can take place by first differencing, or related techniques.

Unfortunately, the requirement that the marginal utility of wealth enters additively, imposes severe restrictions on within-period preferences. Browning, Deaton and Irish (1985) show that both with quantities and with expenditures as dependent variables, additivity of the individual effect requires quasi-homotheticity of preferences. An approach which does not impose restrictions on within-period preferences, but maintains intertemporal separability, is to condition on within-period "full" expenditures rather than marginal utility. This approach has been discussed by Macurdy (1983), although he does not apply it. A recent application is by Blundell and Walker (1986) and by Altonji (1986). Since they have only cross-section data available, they are not able to test whether or not some assumptions underlying the Life Cycle Hypothesis, such as the absence of liquidity constraints, are violated.

In this paper we use an alternative method for estimating the life cycle model which overcomes some of the drawbacks of the approaches mentioned. Our method is similar to the estimation method adopted by McCurdy.

Moreover, we pay attention to the role of demographic factors. Since our data is detailed with respect to consumption but deficient with respect to the number of hours worked by family members, we make the additional assumption that the within period preferences are (weakly) separable between consumption and leisure, so that total after tax income in each period can be taken as given. To allow for second order flexibility within periods, we do not condition on the marginal utility of wealth but on total expenditures within each period. Total expenditures in a period are the result of an allocation decision in which life time wealth is allocated optimally to periods.

Section 2 presents the life cycle model for the consumption-savings decision in rather general terms and discusses some of the estimation strategies which have been proposed in the literature in more detail. In this section we also provide an alternative estimation method, which is closely related to McCurdy's method. Section 3 gives details on functional specifications. Sections 4, 5 and 6 discuss the data and present estimation results. Tests of the first stage part of the model indicate rejection. This does not invalidate the second stage model, which does appear to be consistent with the data. Section 7 concludes.

2. The Life Cycle Hypothesis and Two-Stage Budgeting

Consider a single consumer (or household), who has to plan consumption from the present period t up to a terminal period T in an uncertain environment. We assume that the consumer wants to maximize the following intertemporally additive utility function:

$$U(t) = E_t \sum_{\tau=t}^{T} \left(\frac{1}{1+\rho}\right)^{\tau-t} u(z(\tau),q(\tau)), \tag{2.1}$$

with

E_t:= mathematical expectation conditional on all information available at the beginning of period t (expectations are rational)

$q(\tau)$:= vector of consumption goods in period τ, $\tau = t,\ldots,T$

$z(\tau)$:= vector of taste shifters at age τ

$u(z(\tau),q(\tau))$:= subutility function for period τ, strictly concave

ρ:= rate of subjective time preference.

This utility function is maximized subject to the following constraints:

$$A(\tau) = (1+r)\ A(\tau-1\ ) + y(\tau) - p(\tau)\ q(\tau),\ \tau = t,\ldots,T, \tag{2.2a}$$

$$A(t-1) \text{ given}, \tag{2.2b}$$

$$A(T) = 0 \text{ ("no bequest motive")}, \tag{2.2c}$$

where

$A(\tau)$:= value of assets at the end of period τ

r:= interest rate

$p(\tau)$:= vector of prices in period τ

$y(\tau)$:= labor income in period τ, plus income transfers received in period t, net of taxes.

In this set-up credit markets are assumed to be perfect (no liquidity constraints and equality of borrowing and lending rates). We have also assumed a constant interest rate over time. Relaxation of this assumption has little impact on the empirical model. In our model $p(\tau)$, $z(\tau)$ and $y(\tau)$ are exogenous variables.

The vectors $\nu(\tau) := (p(\tau), z(\tau), y(\tau))'$, $\tau > t$, contain all the variables that are uncertain prior to period t. The random vector $\nu(\tau)$ is realized at the beginning of period τ. With respect to the probability distribution of the $\nu(\tau)$ we only assume the existence of certain moments. The distribution of $\nu(\tau)$ represents the consumer's subjective judgments about future variables.

Optimimization of (2.1) subject to the budget constraints (2.2) implies the following first order conditions for period t[1] (see MaCurdy (1983)):

$$\frac{\partial\, u(z(t),q(t))}{\partial\, q(t)} = \lambda(t)\; p(t) \tag{2.3}$$

$$\lambda(t) = E_t \frac{(1+r)}{(1+\rho)} \lambda(t+1), \tag{2.4}$$

where $\lambda(\tau)$, $\tau = t,\ t+1$, is the Lagrange multiplier associated with the budget constraint of period τ. The quantity $\lambda(\tau)$ is the marginal utility of after tax wealth in period τ. From equations (2.3) and (2.4) it follows that intertemporal additivity allows for two-stage budgeting. In the first stage the household derives total consumption x(t) at time t by equalizing the marginal utility of (suitably discounted) after tax wealth in all periods of the life cycle (see the Euler equation (2.4)). As a result, also the optimal savings-decision is determined in this stage. In the second stage the amount of total expenditures x(t) in period t is allocated to consumption goods according to condition (2.3).

1) For the moment, only interior solutions are assumed.

There is another important implication of the life cycle-rational expectations hypothesis. Rewrite the Euler equation (2.4) as follows

$$\lambda(t+1) = \frac{(1+\rho)}{(1+r)} \lambda(t) + \varepsilon(t+1)), \; E_t\varepsilon(t+1) = 0 \tag{2.4a}$$

Since consumers choose $\lambda(t)$ to satisfy (2.4a) given all the information available at age t, $\varepsilon(t+1)$ will be uncorrelated with lagged variables ($E_t\varepsilon(t+1) = 0$), if the expectations are rational. This econometric implication of rational expectations has been exploited in a number of estimation methods, which have been proposed in the literature and which will be discussed below. In this discussion, the cardinal period specific utility function associated with period t is parameterized as

$$u(z(t),q(t)) = F(u^*(z(t),q(t)),z(t)), \tag{2.5}$$

where F(.) is a monotonically increasing function in $u^*(.)$, and $u^*(.)$ possesses all the conventional properties of a utility function[1)]. The choice of the monotonic transformation is irrelevant in static analysis. However, this is not the case in a multiperiod setting.

Browning, Deaton and Irish (1985) use the first order conditions (2.3) and (2.4) to construct the so-called λ- constant (or Frisch) functions, which take the following form

$$q(t) = f(p(t), z(t), \lambda(t)) \tag{2.6}$$

The general properties of the demand equations (2.6) are described in detail in Browning, Deaton and Irish (B.D.I. from now on) and the use of these functions provides a useful interpretation of life-cycle behavior. Since the marginal utility of wealth $\lambda(t)$ changes only when new information becomes available and since all information about future variables

1) Of course, if $u^*(.)$ represents the intratemporal preferences with respect to q(t), then so does $F(u^*(.), z(t))$. It is a matter of notational convenience to pick an arbitrary representation $u^*(.)$ and then to highlight the cardinal nature of the intertemporal utility function by showing the uniqueness of the transformation F, given $u^*(.)$.

is summarized in this sufficient statistic, one can compute from this equation anticipated (intertemporal) price elasticities.

B.D.I. want to estimate (2.6) by using panel data and by treating ln $\lambda(t)$ as a fixed effect. Fixed effects can be most easily dealt with by differencing, provided that they appear additively in the demand equations, i.e. it is required the Frisch demand of good i is of the form

$$\zeta_i(q_i(t)) = \mu_i \ \ell n \ \lambda(t) + \eta_i(p(t), z(t)), \tag{2.7}$$

where $\eta_i(.)$ and $\zeta_i(.)$ are suitable functions. In an environment of uncertainty one can apply the estimation procedure of B.D.I. if the random variable $\ell n \ \lambda(t+1) - \ell n \ \lambda(t)$ is a sum of an observable variable and a random variable $\omega(t+1)$, which satisfies $E_t\omega(t+1) = 0$. B.D.I. obtain this result in the following way. Rewrite the Euler equation (2.4a) as follows

$$\ln \lambda(t+1) = \ln \frac{(1+\rho)}{(1+r)} + \ln(\lambda(t) + \omega(t+1)), \ E_t\omega(t+1) = 0 \tag{2.8}$$

where $\omega(t+1) = \dfrac{\varepsilon(t+1)(1+r)}{(1+\rho)}$

Now, B.D.I. perform a Taylor expansion of log $(\lambda(t) + \omega(t+1))$ round $\omega(t+1) = 0$ and ignore higher order terms, which leads to the following result

$$\ln \lambda(t+1) \approx \ln(\frac{1+\rho}{1+r}) + \ln \lambda(t) + \omega^*(t+1), \ E_t\omega^*(t+1) = 0$$

where $\omega^*(t+1) = \omega(t+1)/\lambda(t)$.

This equation gives the justification to treat ln $\lambda(t)$ as a fixed effect. Since their strategy relies on some approximations, they make no statements about the statistical properties, such as consistency of the estimation method.

Next to the unknown statistical properties, there is a second disadvantage associated with the use of the approach of B.D.I.. The requirement that ln $\lambda(t)$ enters additively in (2.7), imposes severe restrictions on within period preferences. (see B.D.I. and Blundell, Fry and Meghir (1985)).

An alternative estimation method proposed in the literature (see e.g. Blundell and Walker (1986)) is to condition on within period total (or "full") expenditures rather than marginal utility of wealth. In other words, this approach only requires the estimation of a complete static demand system. By using this approach one does not have to impose a priori restrictions on within period preferences and one can deal easily with corner solutions (see Blundell and Walker (1986) and MaCurdy (1983)). Obviously, with this procedure one can only estimate the parameters of the ordinal utility function $u^*(.)$ in (2.5) and not the parameters of the monotonic transformation $F(.)$. Blundell and Walker (1986) have retrieved intertemporal (constant-λ) price elasticities through the addition of some arbitrarily chosen identifying assumptions on the monotonic transformation $F(.)$.

A major difficulty with this approach is that the same intratemporal demand system can be derived from the optimization of (2.1) subject to (2.2) and a "borrowing" constraint for period t of the form

$$p(t)q(t) \leq M(t), \tag{2.9}$$

where $M(t)$ may be a function of current and future expected income and the stock of assets at the beginning of period t, $A(t-1)$, or

$$M(t) = M(y(t), E_t\; y(t+1),\ldots,E_t\; y(T),\; A(t-1)) \tag{2.10}$$

That this yields the same intratemporal demand system can be seen as follows.

Optimization of (2.1) subject to (2.2) and (2.9) gives the following first order conditions.

$$\frac{\partial\; u(q(t),z(t))}{\partial\; q(t)} = (\lambda(t) + \mu(t))\; p(t) \tag{2.11}$$

$$\lambda(t) = E_t \frac{(1+r)}{(1+\rho)}\; \lambda(t+1) \tag{2.12}$$

$$\mu(t)\; [M(t)-p(t)q(t)] = 0 \tag{2.13}$$

If $\mu(t)$ is equal to zero, the liquidity constraint is not binding. As before, the optimal plan follows from the first order conditions (2.3) and (2.4). However, if $\mu(t)$ is greater than zero, then it follows from (2.13) that total expenditures $x(t)$ are completely determined by the liquidity constraint (2.9). Thus, consumption is not entirely determined by the Frisch demand functions. The optimal allocation of total expenditures over the different goods follows from (2.11) and can be described by a complete demand system. From the first order conditions (2.3) and (2.11) it is clear, that the functional form of the demand systems, which are derived from the two optimization problems mentioned above, are the same. Consequently Blundell and Walker have to assume a priori, that the life cycle hypothesis is true, before they can derive the intertemporal elasticities. On the other hand, the strategy of Blundell and Walker yields estimates that are more robust with respect to the possible presence of liquidity constraints than the constant λ approach.

The estimation method proposed in this paper overcomes some of the drawbacks of the approaches mentioned above. In order to explain our procedure we rewrite the Euler equation (2.4). Combining this equation with (2.3) and (2.5), one obtains the equation

$$F'(t)\frac{\partial\ \psi^*(x(t),\ p(t),\ z(t))}{\partial\ x(t)} = E_t\ \frac{(1+r)}{(1+\rho)}F'(t+1)\frac{\partial\ \psi^*(x(t+1),\ p(t+1),\ z(t+1))}{\partial\ x(t+1)} \tag{2.14}$$

where $F'(t)$ is the derivative of $F(.)$ with respect to $u^*(t)$, $x(t)$ denotes total expenditures, and $\psi^*(.)$ is the indirect utility function corresponding to $u^*(t)$. This equation implies the relation

$$F'(t+1)\ \frac{\partial\ \psi^*(x(t+1),p(t+1),z(t+1))}{\partial\ x(t+1)} =$$

$$\frac{(1+\rho)}{(1+r)}\ F'(t)\ \frac{\partial\ \psi^*\ (x(t),\ p(t),\ z(t))}{\partial\ x(t)}\ [1+\varepsilon(t+1)] \tag{2.15}$$

where $\varepsilon(t+1)$ is a forecast error with $E_t\varepsilon(t+1) = 0$ and consequently uncorrelated with variables observed by period t. Taking natural logs of (2.15) yields

$$\ln\left[F'(t+1)\frac{\partial\,\psi^*(x(t+1),p(t+1),z(t+1))}{\partial\,x(t+1)}\right] = \gamma(t+1) +$$

$$\ln[F'(t)\;\partial\,\psi^*(x(t),\,p(t),\,z(t))/\partial\,x(t)] + \xi(t+1), \tag{2.16}$$

where $\gamma(t+1) = \ln\frac{(1+\rho)}{(1+r)} + E_t\;\ln(1+\varepsilon(t+1))$

$$\xi(t+1) = \ln(1+\varepsilon(t+1)) - E_t\;\ln(1+\varepsilon(t+1))$$

Note that $E_t\ln(1+\varepsilon(t+1))$ may correlate with other variables on the right hand side of (2.16) dated t. We will assume, however, that $E_t\ln(1+\varepsilon(t+1))$ is constant across households. This means among other things that we do not allow for heteroskedasticity of the forecast error. We will also assume that ρ and r are constant across households so that $\gamma(t+1)$ may be treated as a constant.

In our approach we obtain the parameters of the function F(.) and $\psi^*(.)$ by simultaneously estimating a demand system with total expenditures as the conditional variable and equation (2.16). Since the innovation $\xi(t+1)$ will in general be correlated with variables dated t+1, an instrumental variable estimator is required to estimate (2.16)

Our approach is very similar to the estimation procedure which MaCurdy (1983) has used in his empirical analysis. However, he rewrites the Euler equation (2.4) in a different manner. He uses the following equation

$$\lambda(t) = [\partial\;u(q_i(t),\;z(t))/\partial\;q_i(t)]/p_i(t) \tag{2.17}$$

and imposes restrictions on the within period preferences $u^*(.)$, such as additivity. Furthermore, he estimates the parameters of the within period utility function $u^*(.)$ by estimating marginal utilities instead of using a demand system.

The attractive feature of our approach is that in contrast with other methods one can estimate both the parameters of $u^*(.)$ and F(.). Moreover, we can choose a flexible functional form for the within-period preferences and we are able to test some theoretical implications of the life cycle hypothesis along the lines set out by Hall (1978). A consequence of the life cycle hypothesis is that, apart from consumption prices and taste shifters, none of the lagged variables, should have explanatory power with respect to current consumption (see equation (2.15)). We test this implication in the empirical part of the paper by adding lagged income to equation (2.16). It is clear from the equations (2.10), (2.11), (2.12) and (2.13), that lagged income, $y(t)$, has a significant effect on consumption in period $t+1$ if the household is liquidity constrained in period t.

3. Specification of the model

In order to analyse the life cycle model empirically, we adopt explicit functional forms for the within period indirect utility function $F(u^*(t), z(t)) = F(\psi^*(x(t), p(t), z(t)), z(t))$. Suppose $\psi^*(.)$ can be described by the Almost Ideal Demand System (AIDS) utility function of Deaton and Muellbauer (1980)

$$\psi^*(x(t), p(t), z(t)) = \frac{(\ln x(t) - \ln a(z(t), p(t)))}{b(z(t), p(t))}, \tag{3.1}$$

where

$$\ln a(z(t), p(t)) := \alpha_0(z(t)) + \sum_{i=1}^{I} \alpha_i(z(t)) \ln p_i(t) +$$

$$\sum_{i=1}^{I} \sum_{j=1}^{I} \gamma_{ij} \ln p_i(t) \ln p_j(t), \tag{3.2}$$

$$b(z(t), p(t)) := \prod_{i=1}^{I} (p_i(t))^{\beta_i(z(t))},$$

with I the number of goods, z(t) the vector of taste shifters and

$$\sum_{i=1}^{I} \alpha_i(z(t)) = 1; \sum_{i=1}^{I} \beta_i(z(t)) = \sum_{i=1}^{I} \gamma_{ij} =$$

$$\sum_{j=1}^{I} \gamma_{ij} = 0; \gamma_{ij} = \gamma_{ji}. \tag{3.3}$$

The functional form of the monotonic transformation $F(u^*(t))$ is given by

$$F(u^*(t), z(t)) = \beta_0(z(t)) u^*(t) \tag{3.4}$$

This leaves the following function to be maximized subject to (2.2)

$$E_t \sum_{\tau=t}^{T} \left(\frac{1}{1+\rho}\right)^{\tau-t} F(u^*(\tau), z(t)) \tag{3.5}$$

The solution is

$$\frac{\beta_0(z(t))}{b(z(t),p(t))x(t)} = E_t \frac{\beta_0(z(t+1))}{b(z(t+1),p(t+1))x(t+1)} \frac{(1+r)}{(1+\rho)} \tag{3.6}$$

$$w_i(t) = \alpha_i(z(t)) + \sum_{j=1}^{I} \gamma_{ij} \ln p_j(t) +$$

$$\beta_i(z(t)) [\ln x(t) - \ln a(z(t), p(t))], \qquad i = 1,\ldots,I \tag{3.7}$$

where $w_i(t)$ is the budget share of good i in period t.

To incorporate demographic effects into the second stage model (3.7) we parameterize $\alpha_0(z(t))$, $\alpha_i(z(t))$ and $\beta_i(z(t))$, as follows:

$$\alpha_0(z(t)) = \alpha_0 + \rho \ln fs(t) \tag{3.8}$$

$$\alpha_i(z(t)) := \alpha_i + \sum_{j=1}^{fs(t)} \delta_j f^i(a_j(t)) + \theta_i^1 Q_1(t) + \theta_i^2 Q_2(t) \tag{3.9}$$

$$\beta_i(z(t)) := \beta_i + \eta_i \ln fs(t), \tag{3.10}$$

where

$fs(t)$:= family size (i.e. number of household members) in period t

$a_1(t)$:= age of head of household in period t

$a_2(t)$:= age of partner of head of household in period t (if present)

$a_3(t),\ldots,a_{fs}(t)$:= ages of the remaining household members, arranged in order of declining age (if present)

$f^i(.)$:= a cubic spline function with knots at the ages 0, 6, 18, 65 and 79.

δ_j := 1 if j = 1
   := ln (j/(j-1)) if j > 2

$Q_1(t) := 1$ if head of household has a paid job
$:= 0$ otherwise

$Q_2(t) := 1$ if both the head of the household and his or her partner have a paid job
$:= 0$ otherwise

Thus $\alpha_i(z(t))$ depends on family composition and the labor force participation of both the head of the household and his or her partner, whereas $\alpha_0(z(t))$ and $\beta_i(z(t))$ only depend on family size. The definition of δ_j implies a weighting of household members which increases logarithmically with their rank number. The cubic spline $f^i(.)$ is defined on the interval [0,79] and if the age of the j-th member of the household exceeds 79 it is set equal to 79. For this study we restrict the form of the cubic spline $f^i(a_j(t))$ at the end points 0 and 79. In particular we restrict the second order derivatives at 0 and 79 in the following way: $f^{i''}(0) = \frac{1}{2} f^{i''}(6)$ and $f^{i''}(79) = \frac{1}{2} f^{i''}(65)$.

Without these restrictions the data matrix would be extremely ill-conditioned (see Blundell (1980)). Moreover these restrictions permit us to write the cubic spline as follows (see Poirier (1976))

$$f^i(a) = \sum_{j=1}^{5} SPL_j(a)\xi_{ij} \qquad \begin{array}{l} i = 1,\ldots,I \\ a = 0,\ldots,79 \end{array}$$

with $\sum_{j=1}^{5} SPL_j(a) = 1$ for all a.

In this equation, the 80 × 5 values of $SPL_j(a)$ are known and the ξ_{ij} are ordinates of the spline function corresponding to the abscissa values 0, 6, 18, 65, 79. Details can be found in Poirier (1976, ch. 3). Given estimates of ξ_{ij} we can derive estimates of $f^i(a)$. The functional form of $\sum_{j=1}^{fs(t)} \delta_j f^i(a_j(t))$ is given by

$$\sum_{j=1}^{fs(t)} \delta_j f^i(a_j(t)) = \sum_{k=1}^{5} [\sum_{j=1}^{fs(t)} \delta_j SPL_k(a_j(t))]\xi_{ik} =$$

$$\equiv \sum_{k=1}^{5} WSPL_k \xi_{ik} \qquad (3.11)$$

Note that

$$\sum_{k=1}^{5} WSPL_k(t) = 1 + \ln fs(t)$$

By choosing these functional forms for $\alpha_o(z(t))$, $\alpha_i(z(t))$ and $\beta_i(z(t))$, we have adopted an approach similar to Ray's (1983), who has introduced the use of a price and/or utility dependent 'Engel scale'. The Engel scale $m(u^*(t), p(t), fs(t), a_1(t),\ldots,a_{fs}(t))$ corresponding to our functional specification is given by

$$\ln m(u^*(t), p(t), fs(t), a_1(t),\ldots,a_{fs}(t)) = \rho \ln fs(t)$$

$$+ \sum_{i=1}^{I} \Big(\sum_{j=1}^{fs(t)} \delta_j \, f^i(a_j(t)) + \theta_i^1 \, Q_1(t) + \theta_i^2 \, Q_2(t)\Big) \ln p_i(t)$$

$$+ u^*(t) \prod_{i=1}^{I} p_i^{\beta_i} [\prod_{i=1}^{I} p_i^{\eta_i \ln fs(t)} - 1] \tag{3.12}$$

Since we only consider expenditures within one period, we set all prices equal to one, without loss of generality. Inserting (3.8)-(3.11) into (3.7) yields

$$w_i(t) = (\alpha_i - \beta_i \alpha_0) + \sum_{k=1}^{5} WSPL_k(t) \, \xi_{ki} + \theta_i^1 Q_1(t) + \theta_i^2 Q_2(t) +$$

$$+ \beta_i \ln x(t) + \eta_i \ln x(t) \ln fs(t) - (\beta_i \rho + \eta_i \alpha_0) \ln fs(t) -$$

$$- \eta_i \rho \ln^2 fs(t) \tag{3.13}$$

Since $\sum_{k=1}^{5} WSPL_k(t) = 1 + \ln fs(t)$ model (3.13) can be rewritten as

$$w_i(t) = (\alpha_i^* + \beta_i \rho) + \sum_{k=1}^{5} WSPL_k(\xi_{ki}^* - \beta_i \rho) +$$

$$\theta_i^1 Q_1(t) + \theta_i^2 Q_2(t) + \beta_i \ln x(t) + \eta_i \ln x(t) \ln fs(t) -$$

$$- \eta_i \rho \ln^2 fs(t), \qquad (3.13')$$

with
$$\alpha_i^* = \alpha_i - \beta_i \alpha_0 + \eta_i \alpha_0$$
$$\xi_{ki}^* = \xi_{ki} - \eta_i \alpha_0$$

Comparison of these functions to the Working-Leser Engel functions that follow from the standard AIDS-model without demographic effects,

$$w_i(t) = (\alpha_i - \beta_i \alpha_0) + \beta_i \ln x(t), \qquad (3.14)$$

reveals that family composition is allowed to influence both the slope and the intercept of the Engel functions. In addition, total expenditures is scaled by fs^{ρ}. Finally, we have allowed, in a somewhat ad hoc manner, for effects of non-separability of consumption and leisure by the incorporation of 2 dummies in (3.12), that indicate whether a family has zero, one, or two or more earners.

The Euler equation (3.6), which describes the first stage model, can be replaced by

$$\frac{(1+r)}{(1+\rho)} \frac{\beta_0\ (z(t+1))}{b(z(t+1),p(t+1))\ x(t+1)} = \frac{\beta_0\ (z(t))}{b(z(t),p(t))\ x(t)} (1+\varepsilon(t+1)), \qquad (3.15)$$

where $\varepsilon(t+1)$ is a forecast error uncorrelated with variables observed by period t ($E_t \varepsilon_{t+1} = 0$). We have specified the parameter of the monotonic transformation $\beta_o(z(t))$ as follows

$$\ln \beta_0(z(t)) = \zeta_0 + \zeta_1\, Q_1(t) + \zeta_2\, Q_2(t) + \sum_{j=1}^{fs(t)} \delta_j\, h(a_j(t)) \tag{3.16}$$

where

h(.):= cubic spline function with knots at ages 0, 6, 18, 65 and 79 years.

The variables $a_j(t)$ and δ_j were defined before. Given this specification of $\beta_0(z(t))$ and given $p_i(t) = 1$ for all $i = 1,\dots,I$, we may rewrite (3.15) in the following manner

$$\ln x(t+1) = \gamma_0(t+1) + \ln x(t) + \zeta_1\, \Delta\, Q_1(t+1) + \zeta_2\, \Delta\, Q_2(t+1) +$$

$$\Delta \sum_{j=1}^{fs(t+1)} \delta_j\, h(a_j(t+1)) - \left[\sum_{i=1}^{I} \eta_i \ln p_i(t+1)\right] \ln fs(t+1) + \xi(t+1) \tag{3.17}$$

where

$$\gamma_0(t+1) := \ln \frac{(1+\rho)}{(1+r)} + E_t \ln(1+\varepsilon(t+1)) - \sum_{i=1}^{I} \beta_i \ln p_i(t+1)$$

$$\xi(t+1) := \ln(1+\varepsilon(t+1)) - E_t \ln(1+\varepsilon(t+1)),$$

and Δ is a first difference operator. Since we assume that all consumers face the same prices, we may treat the terms $\sum_{i=1}^{I} \beta_i \ln p_i(t+1)$ and $\sum_{i=1}^{I} \eta_i \ln p_i(t+1)$ as constants in a cross-section. Along the same lines as in (3.11) the function $\Delta \sum_{j=1}^{fs(t+1)} \delta_j h(a_j(t+1))$ can be replaced by

$$\Delta \sum_{j=1}^{fs(t+1)} \delta_j h(a_j(t+1)) = \sum_{k=1}^{5} \Delta WSPL(t+1)\, \zeta_{k+2} \tag{3.18}$$

As a result equation (3.17) becomes

$$\ln x(t+1) = \gamma_0(t+1) + \ln x(t) + \zeta_1 \Delta Q_1(t+1) + \zeta_2 \Delta Q_2(t+1) + \sum_{k=1}^{5} \Delta WSPL(t+1)\, \zeta_{k+2} - \gamma_1(t+1) \ln fs(t+1) + \tilde{\xi}(t+1), \quad (3.19)$$

where $\gamma_1(t+1) = \sum_{i=1}^{I} \eta_i \ln p_i(t+1)$

Thus the relative change of the total expenditures in period t+1, $\Delta \ln x(t+1)$, can be expressed as a function of changes in the labor force participation of both the head of the household and his or her partner, and family composition. Once again, the incorporation of the labor force participation dummies can be seen as a primitive way to allow for a possible non-separability between consumption and leisure.

4. Data, Identification and Estimation

The data used to estimate the model developed above comes from the 1980-1981 Consumer Expenditure Survey of the Netherlands Central Bureau of Statistics. We have used 1579 observations of households whose expenditures, income, family composition, occupational status, etc., are known for both 1980 and 1981. Expenditures are classified according to the following seven categories

1. Food (including outdoor meals)
2. Housing (including rent, maintenance, appliances, tools, heating, electricity)
3. Clothing and footwear
4. Personal care and medical expenditures (including payments for domestic services)
5. Education and recreation (including holidays, smoking, stationary and subscriptions)
6. Transportation (including public transportation, bicycles, mopeds, motor cycles, cars)
7. Other expenditures.

Table 1 gives some sample information on the budget shares of these categories and some general household characteristics.

The complete model consists of (3.13') and (3.19), with error terms added to (3.13'). We estimate model (3.13') for period t+1. The complete model can be summarized as follows:

Table 1 Sample means and standard deviations of some variables

	1980		1981	
	Mean	Standard deviation	Mean	Standard deviation
Budget shares				
1. Food, w_1	0.218	0.072	0.215	0.070
2. Housing, w_2	0.313	0.106	0.331	0.107
3. Clothing/Footwear, w_3	0.083	0.044	0.079	0.043
4. Personal care and medical expenditure, w_4	0.130	0.044	0.132	0.044
5. Education and recreation, w_5	0.140	0.075	0.130	0.074
6. Transportation, w_6	0.105	0.089	0.102	0.086
7. Other expenditures, w_7	0.012	0.018	0.011	0.017
General Characteristics of the households				
1. Total expenditures, x (Dfl × 1,000)	33,019	13,970	33,248	14,070
2. After tax income, y (Dfl × 1,000)	35,590	15,004	37,035	15,955
3. Family size, fs	2.985	1.394	3.003	1.394

$$\ln x(t+1) = \gamma_0(t+1) + \ln x(t) + \sum_{k=1}^{5} \Delta\, WSPL_k(t+1)\, \zeta_{k+2}$$

$$\zeta_1\, \Delta\, Q_1(t+1) + \zeta_2\, \Delta\, Q_2(t+1) + \gamma_1(t+1) \ln fs(t+1) + \tilde{\xi}(t+1) \qquad (4.1)$$

$$w_i(t+1) = (\alpha_i^* + \beta_i \rho) + \sum_{k=1}^{5} WSPL_k(t)(\xi_{ki}^* - \beta_i \rho) + \theta_i^1 Q_1(t+1) + \theta_i^2 Q_2(t+1)$$

$$+ \beta_i \ln x(t+1) + \eta_i \ln x(t+1) \ln fs(t+1) - \eta_i \rho \ln^2 fs(t+1) +$$

$$+ \omega_i(t+1) \qquad (4.2)$$

$i \in \{1,\ldots,I\}$ (I=number of goods)

$$\gamma_0(t+1) = \ln \frac{(1+r)}{(1+\rho)} - E_t \ln(1+\varepsilon(t+1)) - \sum_{i=1}^{I} \beta_i \ln p_i(t+1)$$

$$\gamma_1(t+1) = - \sum_{i=1}^{I} \eta_i \ln p_i(t+1)$$

$$\alpha_i^* = \alpha_i - \beta_i \alpha_0 + \eta_i \alpha_0$$

$$\xi_{ki}^* = \xi_{ki} - \eta_i \alpha_0$$

$$\sum_{i=1}^{I} \alpha_i = 1; \quad \sum_{i=1}^{I} \xi_{ki} = 0; \quad \sum_{i=1}^{I} \eta_i = 0; \quad \sum_{i=1}^{I} \beta_i = 0$$

$$\sum_{i=1}^{I} \theta_i^1 = 0; \quad \sum_{i=1}^{I} \theta_i^2 = 0.$$

Since the budget shares add up to one, there is one equation in (4.2) that can be dropped in estimation. We have chosen to drop the last one. With respect to the stochastic specification of the model we make some simplifying assumptions. First we assume that the distribution of $\tilde{\xi}(t+1)$ in (4.1) is the same across consumers. Consequently, $\gamma_0(t+1)$ is a period specific parameter, which has the same value for all consumers.

Furthermore, we assume $\omega(t+1) := (\tilde{\xi}(t+1), \omega_1(t+1), \ldots, \omega_6(t+1))' \equiv (\tilde{\xi}(t+1), \omega^*(t+1))'$ to be (normally) independently and identically distributed across observations with mean zero and variance covariance matrix V, given by

$$V = \begin{bmatrix} \sigma^2_{\tilde{\xi}} & V'_{\omega^*, \tilde{\xi}} \\ V_{\omega^*, \tilde{\xi}} & V_{\omega^*, \omega^*} \end{bmatrix} \tag{4.3}$$

with V symmetric positive definite but otherwise unrestricted. We have estimated (4.1) and (4.2) separately by using (non-linear) two stage least squares methods for both equations and by ignoring the restriction $\gamma_1(t+1) = -\sum_{i=1}^{I} \eta_i \ln p_i(t+1)$. We need an instrumental variable estimator in (4.1), because the taste shifters dated t+1 may be correlated with $\tilde{\xi}(t+1)$. We use a number of household characteristics like $Q_1(t)$, $Q_2(t)$, region, family size etc.. Since our panel consists of 2 waves we have only levels and not first differences of these instruments, such as $\Delta Q_1(t)$, at our disposal. Therefore, the correlation between the instruments and the endogenous variables on the right hand side tends to be small. Some instruments deserve further comment: given the size and age composition of the family in 1980, we have computed the following variables

$$WSPLI_k(t) := \sum_{j=1}^{fs(t)} \delta_j \; SPL_k(a_j(t)+1)$$

Good instruments for $\Delta\, WSPL_k(t+1)$ may be

$$\Delta\, WSPLI_k(t) = WSPLI_k(t) - WSPL_k(t) \qquad k = 1,\ldots,5 \tag{4.4}$$

Since $\sum_{k=1}^{5} WSPL_k(t) = \sum_{k=1}^{5} WSPLI_k(t) = 1 + \log fs(t)$, we have added only four of the five variables in (4.4) to the set of instruments.

We have to estimate model (4.2) by means of nonlinear two stage least squares, because $\ln x(t+1)$ and $\ln x(t+1) \ln fs(t+1)$ are endogenous variables, due to assumption (4.3). We have used the following instruments $\ln x(t)$ and $\ln x(t) \ln fs(t+1)$. (We assume that we may treat taste shifters in period t+1, such as ln fs(t+1), as exogenous variables in the second stage model.)

As a result our estimation procedure will yield consistent, but not fully efficient estimates of the parameters in (4.1) and (4.2).

Finally, we pay some attention to the identification of the structural parameters in model (4.2). Under the statistical assumptions made, all reduced parameters can be estimated consistently. However, the reduced form parameters do not contain enough information to identify all structural form parameters. This can be seen as follows: β_i, η_i, θ_i^1, θ_i^2 are reduced form parameters and hence identified. Next use the reduced form parameter corresponding to $\ln^2 fs(t)$ to determine ρ. Then, it is easy to see that the parameters ξ_{ki}^* and α_i^* are also identified. However, knowing ξ_{ki}^* and α_i^* still leaves us one piece of information short to be able to solve for the structural parameter α_i, α_0 and ξ_{ki}.

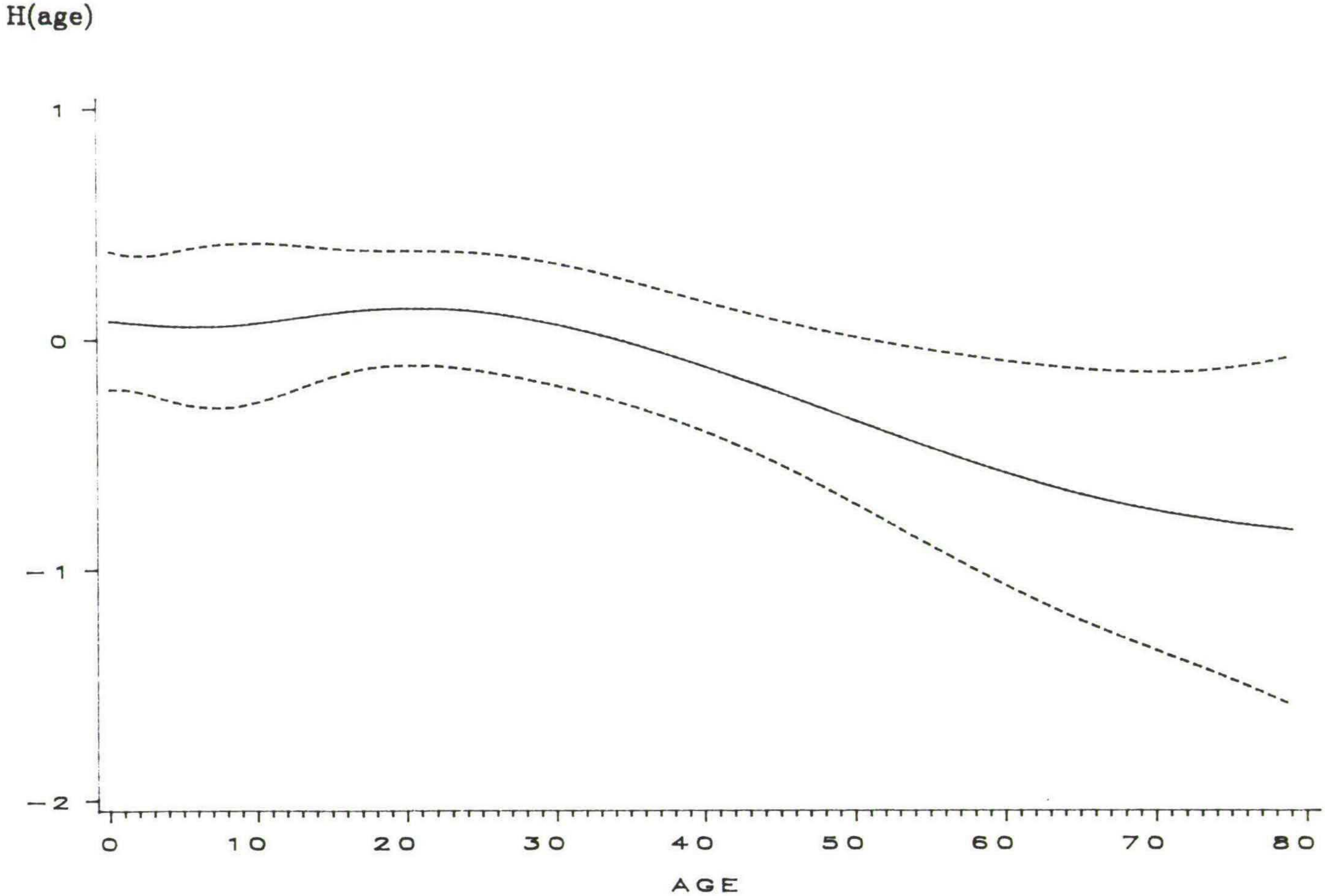

FIG. 5.1: Estimated age function (cubic spline), H(age), plus the corresponding confidence interval.

5. Results for the first stage

The parameter estimates for equation (4.1) are given in Table 2. The R^2-value is quite acceptable, though not surprising for a model with a lagged dependent variable. For the rest, the empirical results are a bit disappointing, because most coefficients do not differ significantly from zero. Undoubtedly, this is partly due to the available instruments, which do not correlate highly with the explanatory variables.

The age function drawn in Fig. 5.1 also has wide confidence intervals (defined as 1.96 times the standard error of the estimate of the function value), and a test of the hypothesis of a constant age function does not lead to rejection ($F(4,1570) = 1.83$), although it is close (The probability of an $F(4,1570)$-statistic exceeding 1.83 equals 0.12.). From (2.5), (3.4) and (3.16) it is clear that the age function serves to weight utility in different periods. The shape of the age function suggests that beyond the age of twenty one tends to given lower weights to consumption at older ages (over and above the effect of the subjective discount rate). Since the taste shift is foreseen (i.e. "rational"), the *ceteris paribus* effect of age on consumption is a monotonic decrease after the age of twenty.

Table 2 Estimation results for the first stage (asymptotic t-values in parentheses)

Equation 4.1

$\gamma_0(1981) = 0.030$ (1.786)
$\gamma_1(1981) = 0.002$ (0.112)

Labor participation dummies

$\zeta_1 = -0.025$ (-0.309)
$\zeta_2 = 0.010$ (0.116)

total expenditures

$\gamma_2 = 1$

$\mathrm{var}(\eta(1981)) = 0.059$

Ordinates of the cubic spline function

age	ordinates
0	0.080 (0.527)
6	0.053 (0.297)
18	0.128 (1.002)
65	-0.679 (-2.446)
79	-0.833 (-2.156)

$R^2 = 0.710$

We have also estimated an equation of the following form by means of 2SLS.

$$\ln x(t+1) = \alpha_0(t+1) + \alpha_1 \ln x(t) + \alpha_2 Q_1(t+1) + \alpha_3 Q_2(t+1)$$

$$\alpha_4 Q_1(t) + \alpha_5 Q_2(t) + \sum_{j=1}^{5} \alpha_{j+5} WSPL_j(t+1)$$

$$+ \sum_{j=1}^{5} \alpha_{j+10} WSPL_j(t) + \xi(t+1) \qquad (5.1)$$

Note that equation (4.1) is nested in (5.1).[1] We can thus use an asymptotic F-test to investigate whether the restrictions implied by (4.1) are valid. The test rejects the restriction decisively $F(7,1563) = 27.82$. A possible explanation is, that the functional form of the monotonic transformation F is not correct.

Finally, we have added lagged income to equation (5.1). The corresponding coefficient differs significantly from zero ($t(1562) = 5.107$).

One can interpret this result as a contradiction of the life cycle-rational expectations hypothesis, which says that of the lagged variables only lagged consumption and taste shifters (in our case demographic factors and labor participation dummies) should have a nonzero coefficient in such a regression (see Hall (1978)). A possible cause for the departure of the life cycle-rational expectation hypothesis is the presence of liquidity constraints. Also, the expectations of consumers may not be rational.

The significance of the lagged income coefficient may also be due to a violation of some other assumptions we made. We assumed, for example:

1. The within period preferences are weakly separable between consumption and leisure.
2. The consumer is not subject to (rational) habit formation.

1) Note that $\sum_{j=1}^{fs(\tau)} WSPL_j(\tau) = 1 + \log fs(\tau)$, $\tau = t, t+1$.

3. The coefficient $\gamma_0(t+1)$ is the same across individuals. This means that we neither allow for a varying rate of time preference ρ nor for heteroskedasticity of the forecast error. One can somewhat relax this assumption by treating $\gamma_0(t+1)$ as a random effect, provided that it does not correlate with variables dated t.

If assumptions 1 or 2 are violated, the within period demand system will be misspecified. The violation of the third assumption, or non-rational expectations, or liquidity constraints, need not induce misspecification of the second stage model. Maintaining assumptions 1 and 2 we present estimation results for the within period demand system in the next section.

6 Results for the Second Stage

Parameter estimates for model (4.2) are given in Table 4. Once more, the results for the spline functions are given in graphs, see Figures 6.1 through 6.6. The R^2-s are rather low, which suggests that it might be useful to add explanatory variables to the model. Especially lagged budget shares (as an indication of (myopic) habit formation) may be important determinants of current budget shares. One should note, however, that although the explanation of variation in budget shares across households leaves something to be desired, the explanation of expenditures is much better. Rewriting (4.2) in terms of expenditures reveals that more than 50% of the variance of expenditures across households is explained by the model.

In our model the expenditure elasticity of good i is equal to

$$1 + \frac{\beta_i + \eta_i \ln fs(t)}{w_i}$$

The resulting expenditure elasticities for different family sizes are displayed in Table 3.

Table 3 Expenditure elasticities for different family sizes (evaluated at the 1981 sample means of $w_1, \ldots, w_6, w_7$)

fs good	1	2	3	4
1. food	0.740	0.691	0.663	0.643
2. housing	0.964	0.960	0.957	0.955
3. clothing	1.063	1.125	1.161	1.186
4. personal care	1.061	0.856	0.736	0.651
5. education	1.092	1.215	1.287	1.338
6. transportation	1.490	1.633	1.716	1.776
7. other	0.364	0.679	0.863	0.994

We observe that food and housing are necessities irrespective of the size of the family. Personal care and medical expenditures are also necessities, if the family size is at least equal to two.

The other consumption categories are luxuries. The estimate of $\rho(=0.24)$ implies substantial economies of scale: An increase of family size by 10% increases the cost of maintaining a certain utility level by only 2.4% (cf. (3.12) with all prices equal to one). The estimates of the θ-s show that one and two-earner families have a lower budget share for food and a higher budget share for personal care, medical expenditures and transportation than households with zero earners. For the rest, differences are slight.

Table 4 Second stage estimates (t-values in parentheses)

ρ = 0.236

α_1^{**} = 0.248 (4.78)	β_1 = -0.056 (-5.65)	η_1 = -0.015 (-1.59)
α_2^{**} = 0.433 (5.07)	β_2 = -0.012 (-0.75)	η_2 = -0.002 (-0.15)
α_3^{**} = 0.068 (1.91)	β_3 = 0.005 (0.78)	η_3 = 0.007 (1.04)
α_4^{**} = -0.047 (-1.31)	β_4 = 0.008 (1.18)	η_4 = -0.039 (-5.69)
α_5^{**} = 0.220 (3.66)	β_5 = 0.012 (1.09)	η_5 = 0.023 (2.13)
α_6^{**} = 0.040 (0.60)	β_6 = 0.050 (3.96)	η_6 = 0.021 (1.80)
α_7^{**} = 0.038	β_7 = -0.007	η_7 = -0.005
θ_1^1 = -0.013 (-2.43)	θ_1^2 = -0.024 (-3.36)	R_1^2 = 0.2152
θ_2^1 = 0.004 (0.42)	θ_2^2 = -0.000 (-0.01)	R_2^2 = 0.1044
θ_3^1 = -0.003 (-0.78)	θ_3^2 = -0.005 (-0.91)	R_3^2 = 0.0388
θ_4^1 = 0.005 (1.39)	θ_4^2 = 0.016 (3.22)	R_4^2 = 0.1019
θ_5^1 = -0.001 (-0.13)	θ_5^2 = 0.008 (0.10)	R_5^2 = 0.0764
θ_6^1 = 0.008 (1.17)	θ_6^2 = 0.011 (1.19)	R_6^2 = 0.1639
θ_7^1 = 0.000	θ_7^2 = -0.007	

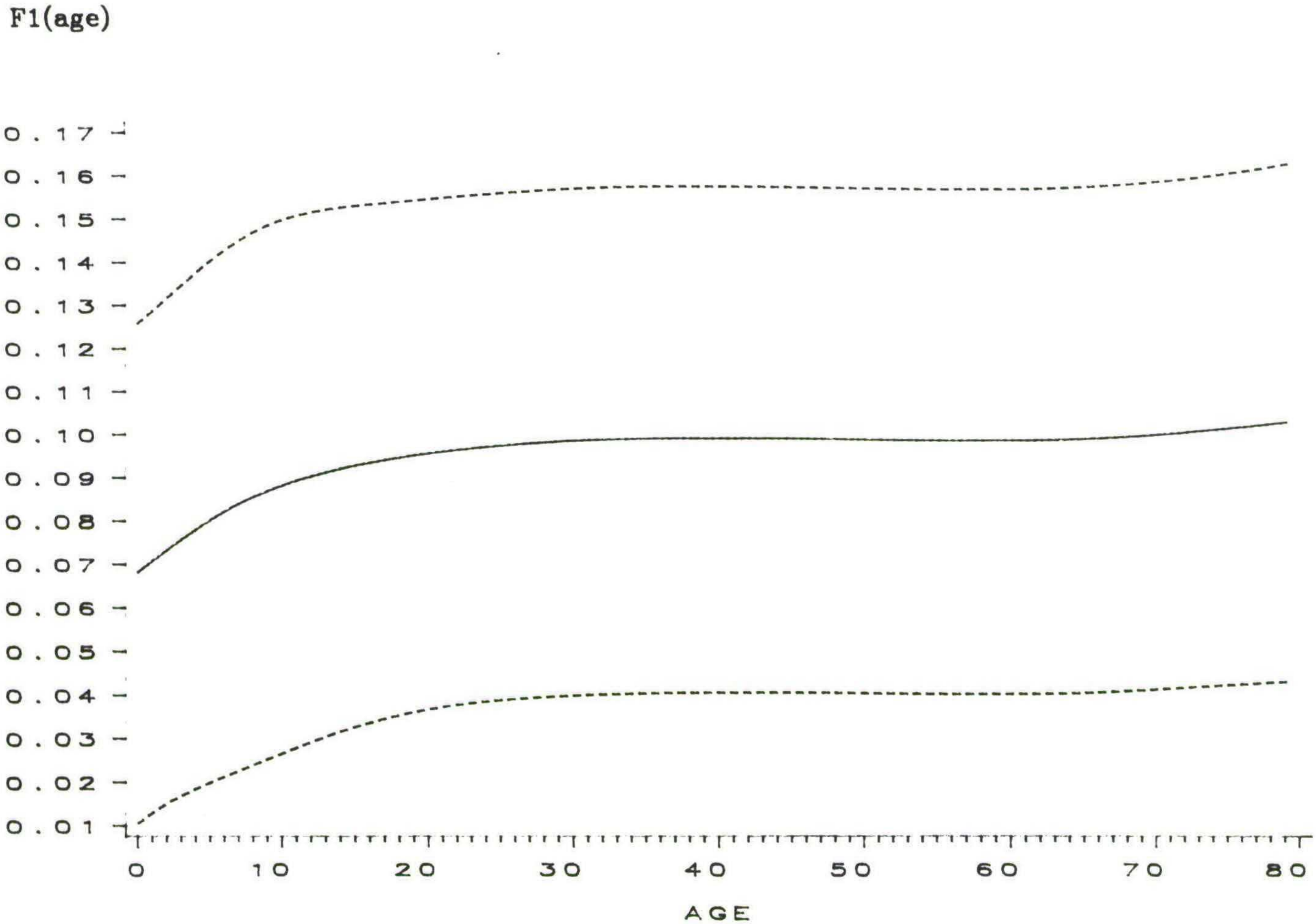

FIG. 6.1: Estimated age function (cubic spline), F1(age), of food plus the corresponding confidence interval.

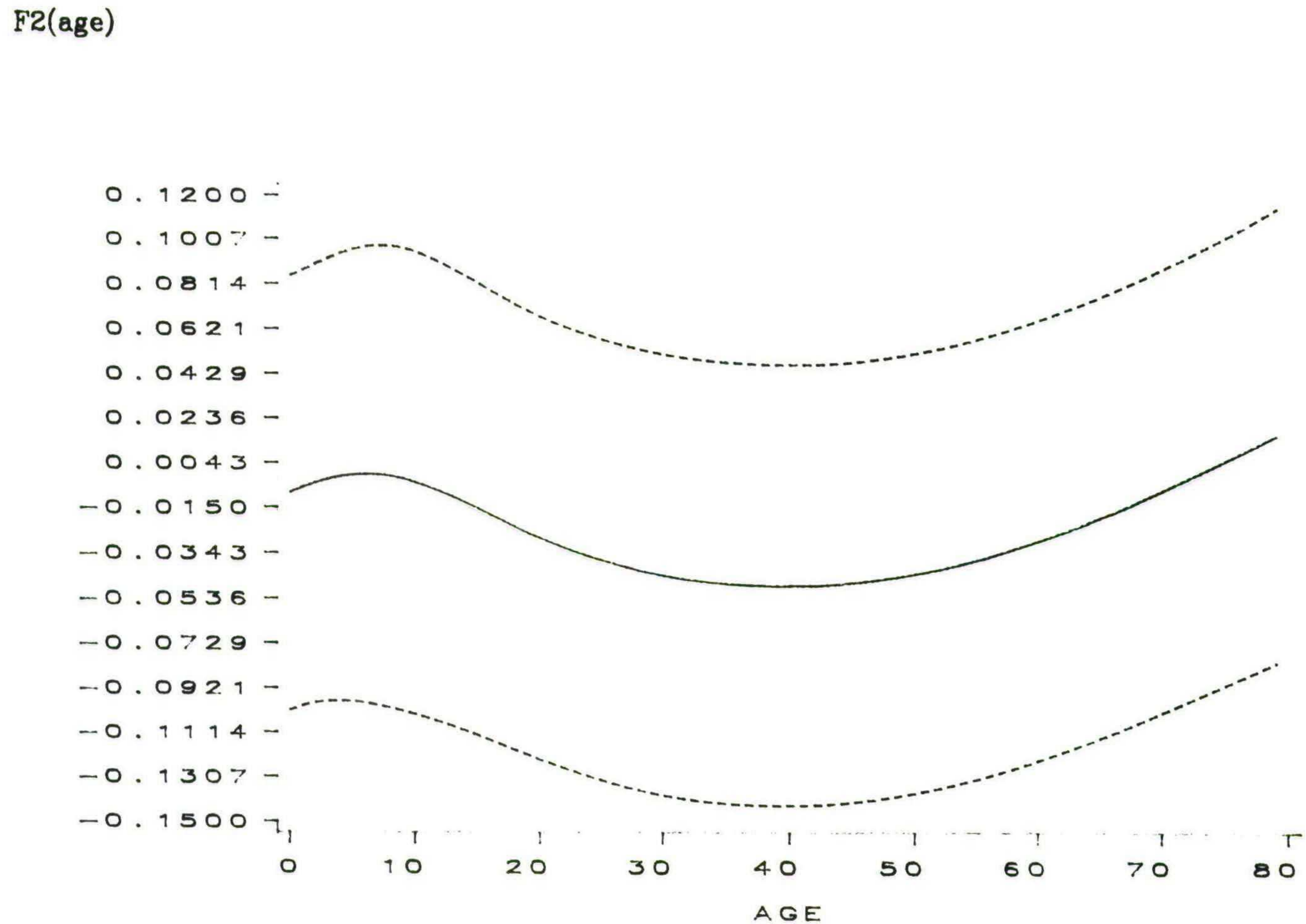

FIG. 6.2: Estimated age function (cubic spline), F2(age), of housing plus the corresponding confidence interval.

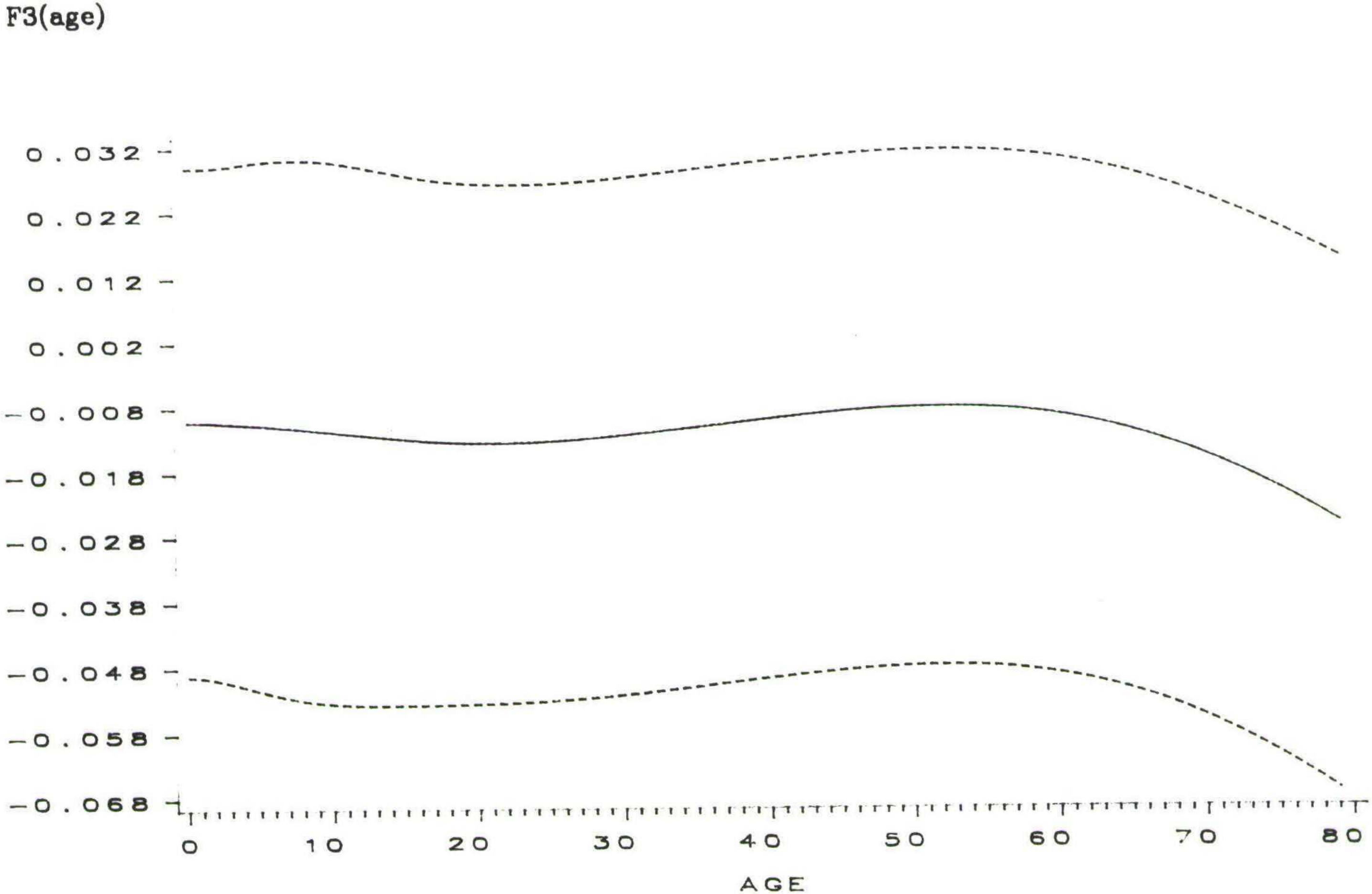

FIG. 6.3: Estimated age function (cubic spline), F3(age), of clothes, footwear plus the corresponding confidence interval.

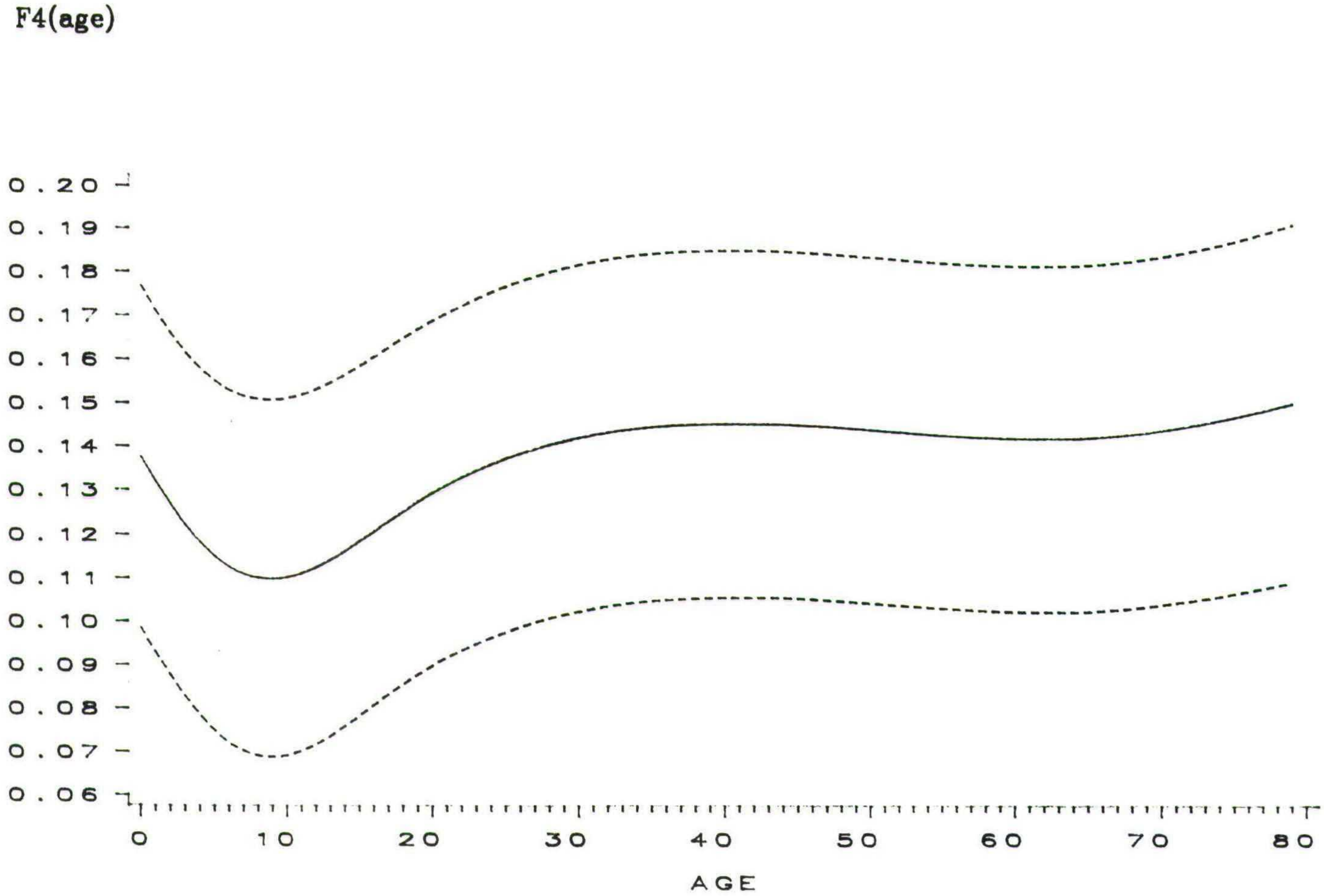

FIG. 6.4: Estimated age function (cubic spline), F4(age), of personal and medical care plus the corresponding confidence interval.

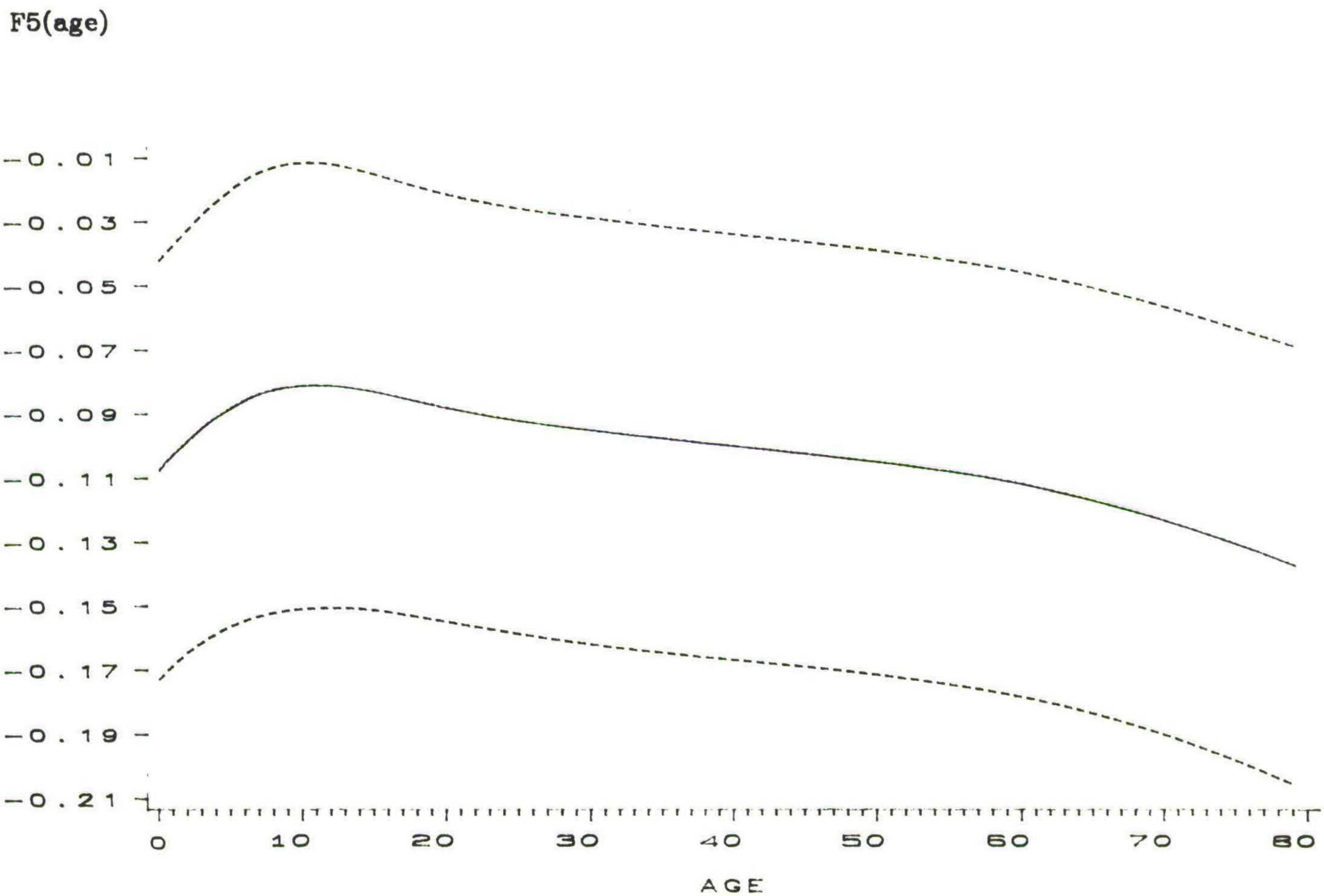

FIG. 6.5: Estimated age function (cubic spline), F5(age), of education and recreation plus the corresponding confidence interval.

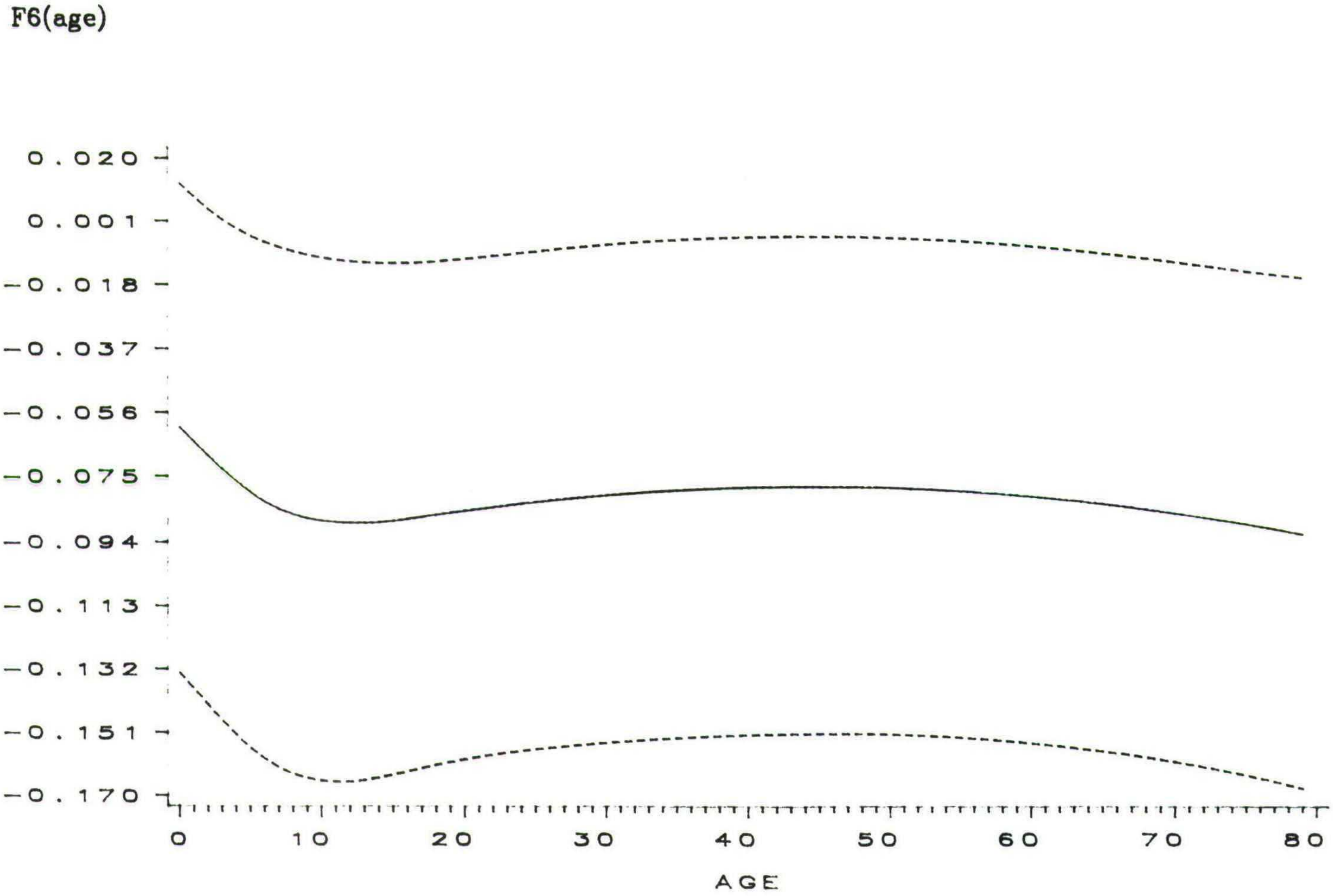

FIG. 6.6: Estimated age function (cubic spline), F6(age), of transportation plus the corresponding confidence interval.

Generally, our attempt to make the specification of demographic effects as general as possible, makes it difficult to attach a direct interpretation to the parameter estimates. This is slightly different for the age functions incorporated in (3.13) since these represent an additive effect on the budget share of a good. The age functions are presented in Figures 6.1 through 6.6. The small seventh expenditure category has been omitted. Fig. 6.1 suggests that food consumption goes up till one reaches adulthood and afterwards remains constant. For housing it would seem that in particular the young and the old need a lot of space. It should be noted, of course, that people in the 30-50 range frequently will have children in the younger age-range. And it is only the sum of the age effects, logarithmically weighted, which appears in (3.13).

Fig. 6.3 suggests that the need for clothing only starts dropping off beyond the retirement age. The demand for personal and medical care (Fig. 6.4) shows a dip at the healthy ages between 3 and 25. Old people do not consume more medical care than younger people since in The Netherlands health insurance premiums are in principle constant across age groups. Not surprisingly, Fig. 6.5 shows that education and recreation are least consumed by the very young and the very old. Finally, Fig. 6.6 suggests that the budget share of transportation are more or less constant across the life cycle, with a slight dip around the age of ten.

7 Concluding Remarks

The life-cycle hypothesis provides a convenient and powerful approach to the modelling of consumption and savings decisions. Even though the first stage model is rejected by the data, the additive separability of the intertemporal utility function allows for a flexible specification of the second stage expenditure allocation decision, which is not rejected by the data.

The rejection of the first stage model suggests the need to relax the stringent assumption of perfect capital markets. The low R^2 s for the second stage model indicate the need to pay more attention to the influence of taste shifters. In Alessie and Kapteyn (1986) we have therefore incorporated habit formation and preference interdependence into the second stage model.

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